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A DESIGN TEACHING METHOD USING SHAPE GRAMMARS

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ABSTRACT

This article describes a design teaching experience conducted by graduate students of the Post Graduate Program in Civil Engineering and applied to a group of six undergraduate students of the Architecture Course of the School of Civil Engineering, Architecture and Urban Design, at UNICAMP – State University of Campinas. The teaching proposal was part of a graduate course in design methods and its goal was to develop and test an innovative design teaching proposal whose emphasis was given to the understanding of the process of design as a shape-generation method. The Shape Grammar system was chosen to develop the described methodology, where a set of geometric rules describes a specific architectural style and can be applied step by step to create new designs. These grammars can be developed in two or three dimensions. Frank Lloyd´s Praire Houses where used to better identify and apply this method.

Key-words: Shape Grammar, Design Method, architectural design, design teaching

RESUMO

Este artigo é um relato de uma experiência realizada na disciplina “Metodologia do Projeto Arquitetônico”, do Programa de Pós-Graduação em Engenharia Civil da Faculdade de Engenharia Civil, Arquitetura e Urbanismo, da UNICAMP – Universidade Estadual de Campinas, e aplicada em alunos da graduação do curso de Arquitetura e Urbanismo, da mesma instituição. O objetivo da experiência era a aplicação de uma metodologia de ensino de projeto que utiliza ferramentas

específicas de geração de formas, análise de linguagens arquitetônicas e conceituação projetual. Para o desenvolvimento desta metodologia foi escolhido o Shape Grammar, cujo método se resume em um conjunto de regras que aplicadas passo a passo podem descrever linguagens de design já existentes ou gerar linguagens originais em duas ou três dimensões. Para melhor identificar e empregar este método, foi utilizado como exemplo de aplicação, as casas de pradaria de Frank Lloyd Wright.

Palavras-chave: Gramáticas da forma, Metodologia de projeto, projeto arquitetônico, ensino de projeto

1. Introdução

Although design education has been discussed widely, the traditional studio method, in which students develop their design projects under the advice of an experienced architect-instructor, is still the prevalent system. The studio method has been described by Schön (1987) as a reflective conversation between a student and his coach. The design process and its development language (drawings, models) are considered complex. So-called "wicked problems" are part of design, and this makes the application of classical scientific investigation methods difficult. Computer-aided design in architectural courses has also had an influence on teaching and most schools are still searching for appropriate ways of balancing design activities between paper and computer (Nicol & Pilling, 2000).

The traditional studio method does not provide the novice student with the tools and methods he or she needs to develop a design that is based not only on functional issues, but also on formal ones. On the other hand, architectural education introduced as pure art, without regard to users and their needs, is also criticized (SALAMA, 1997).

Such problems of design education were discussed in a graduate class on design methods. New approaches to studio activities were proposed in the Doctoral Program of the School of Civil Engineering, Architecture and Urban Design at the State University of Campinas, UNICAMP - Brazil in the second semester of 2005. Students in this class were introduced to the theoretical literature on design methods and discussed the advantages and disadvantages of several educational experiments (Altshuller, 1946; Boden, 1991; Lawson, 1997). Six different design- teaching methods commonly used in Brazil and abroad were identified and students' learning curve was discussed in relation to each method:

1. Traditional studio teaching based on a given architectural program and site for a specific design project.
2. Traditional studio teaching based on the discussion of an architectural program, elaborated by students and its appropriate urban setting.
3. Introduction of an actual, local design problem into the studio and the development of a participatory process, with problem analysis and solution justification by students.
4. Teaching design combining architectural theory with practical design activities.
5. Teaching design using "form generation" methods and formal architectural languages.

6. Teaching design using specific CAD design tools.

Finally, proposals were made to improve design teaching. This paper presents one of the innovative teaching methods developed in this course. The proposal described below can be associated to the fifth design teaching method described above. It introduced the shape grammar formalism (Stiny, 1972) as a generative system for the development of designs.

1.1. Shape grammars

Shape grammars are graphical production systems that provide a formal mechanism for generating compositions based on shapes and their spatial relationships by specifying methods to replace parts of shapes with others (Liew, Haldane, 2002). They have been used for the last thirty years since the first publications by Stiny (1972). A shape is composed of a finite collection of labelled or unlabeled points, lines, planes, areas, or solids. A rule in shape grammars can be written in the form A → B where A and B are shapes. When this rule A → B is applied, an instance of shape A is replaced with shape B. There are also parametric shape grammars which mean the shapes have parameters that can be adjusted (Stiny 1980, 1990). Shape grammars can be divided into two categories: analytical and original. Analytical grammars are developed to describe and analyze historical styles. Original grammars are concerned with the creation of new and original designs.

Figure 1a exemplifies a shape grammar based on a vocabulary (composed of a single oblong) and one simple addition rule. Despite the simplicity of this grammar described by Knight(1999) it can generate a number of different designs within a language (Fig. 1b).

Fig. 1a: Vocabulary Addition rule

Fig. 1b: 16 different possible designs created by the grammar (Knight, 1999)

The use of grammars for creative design has not been explored as deeply as the use of grammars for analytical studies (Colakoglu, 2002). Creativity in rule-based design lies in the

creation of the rules. Rules can be modified and expanded at every stage of a design process allowing the designer to make explicit his/her design knowledge in a structured framework. The designer controls form-generation by explicitly defining the criteria for new designs that fit a given context.

Shape grammars have been used in architecture to generate alternatives and variations of specific architectural models, such as the Palladian villa grammar (Mitchell, 1996). A set of geometric rules describes a specific architectural style and can be applied step by step to create new designs. These grammars can be developed in two or three dimensions.

The Prairie Houses of Frank Lloyd Wright have also been analyzed from a shape grammar perspective. Koning and Eizenberg developed the language of Prairie Houses in 1981. Wright's architectural design principles, found in his early work, the Prairie Houses, can be traced back to his childhood. It is said that Frank Lloyd Wright was educated through the Froebel method, which gave him his exceptional spatial abilities.

Froebel was an educator of the 19th century who developed what are called today the Froebel blocks to teach children proportions and mathematical rules (Fig 2). Friedrich Froebel, was a Prussian educator and the first to recognize toys as important tools in the class room. He lived from 1782 till 1852 and valued activity and freedom of movement for children in schools. He was influenced by Pestalozzi and established the very first Kindergarten.

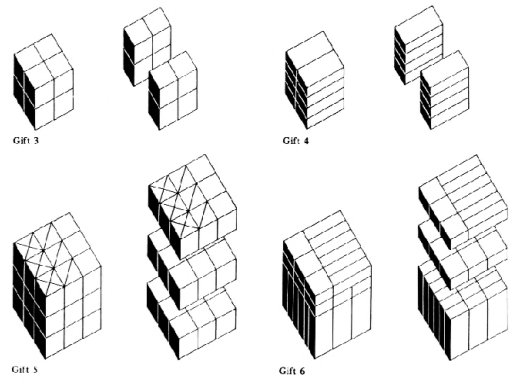

Figure 2. Froebel blocks (Stiny, 1980)

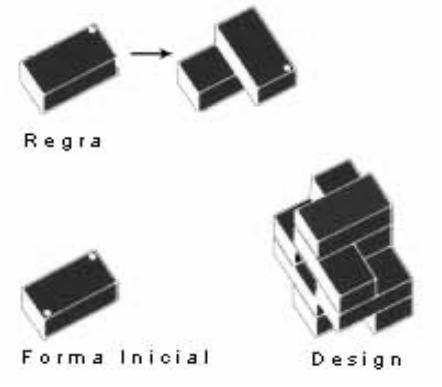

Figure 3 - Kindergarten Grammar (Stiny, 1980)

Stiny (1980) developed a shape grammar using the Froebel blocks as his first three-dimensional vocabulary. Some principles of the "Kindergarten Grammar" are shown in figure 3.

One year later, Koning and Eizenberg published their study on the Prairie House language, developing an extremely detailed grammar with which it is possible to generate all the houses designed by Wright and many more in the style (Fig. 4)

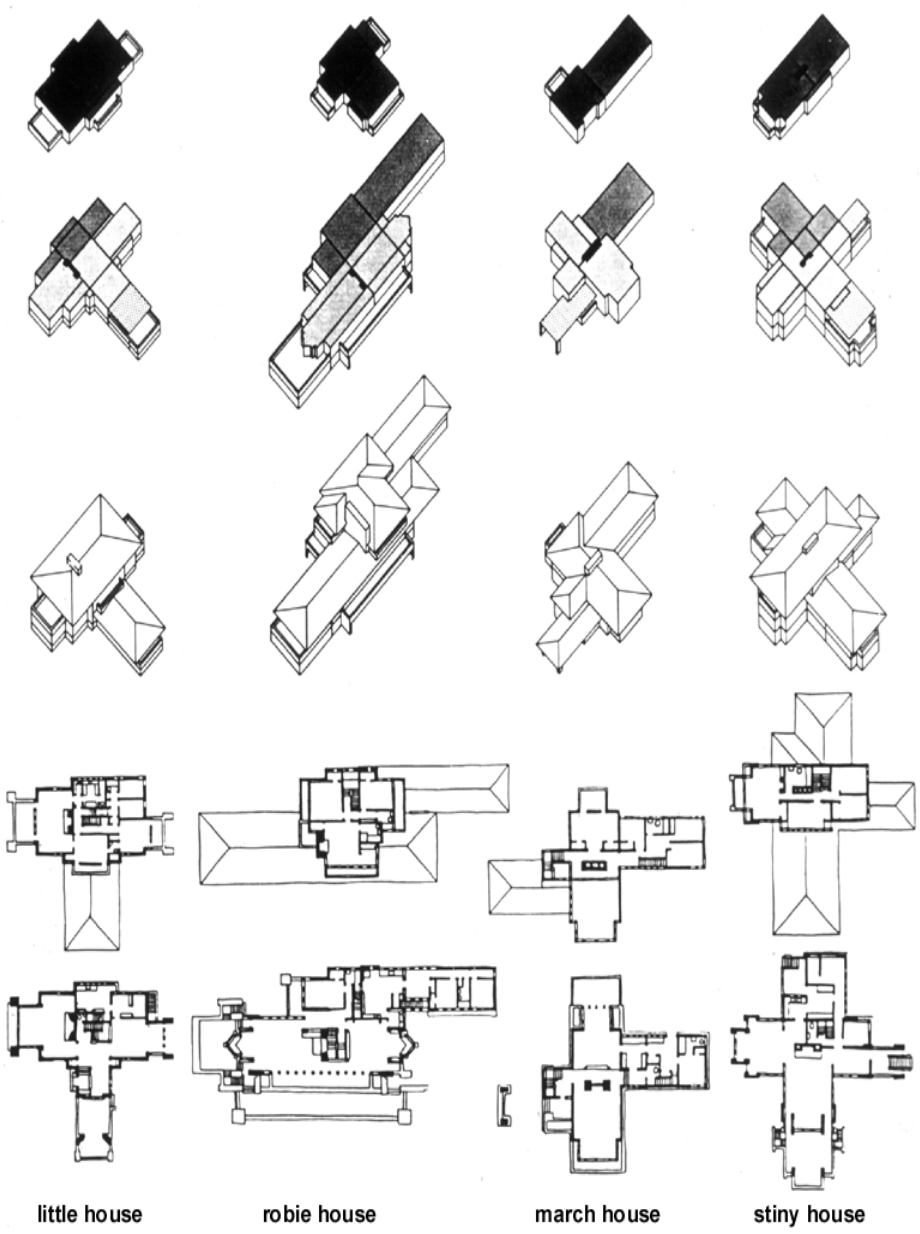

Figure 4. Frank Lloyd Wright´s Prairie House Grammar (Koning and Eizenberg, 1981)

Although Koning and Eizenberg's study presents almost one hundred different design rules, ranging from basic volumetric composition through final detailing, the essence of the prairie house grammar is expressed by the main five rules shown in Figure 5 (the rule numbers used here differ from the numbers used in Koning and Eizenberg's paper). For simplicity's sake, the rules that introduce the basement floor, the labels and all the details have been ignored here. The first rule in this simplified version of the grammar introduces the chimney, an important architectural element in Wright's designs. This rule sets the fireplace at the origin (0,0,0) of a drawing. The second rule adds the living area to the fireplace in four different ways. The third rule connects the kitchen and service area to this composition. At this point the central core of a

house is established and a main axis is formed. Additions may occur according to the fourth rule and with these, secondary axes are established. Depending on their position, these additions may assume different functions in the composition of the house. If they are adjacent to a service area they will necessarily become a service area; if they are adjacent to a living area they will necessarily become a living area; and if they are between both, they may become either one. Rule five specifies these functions. At this point, the core unit of the house is ready. With only these rules it is possible to generate what the authors of the Prairie House grammar call a "basic composition".

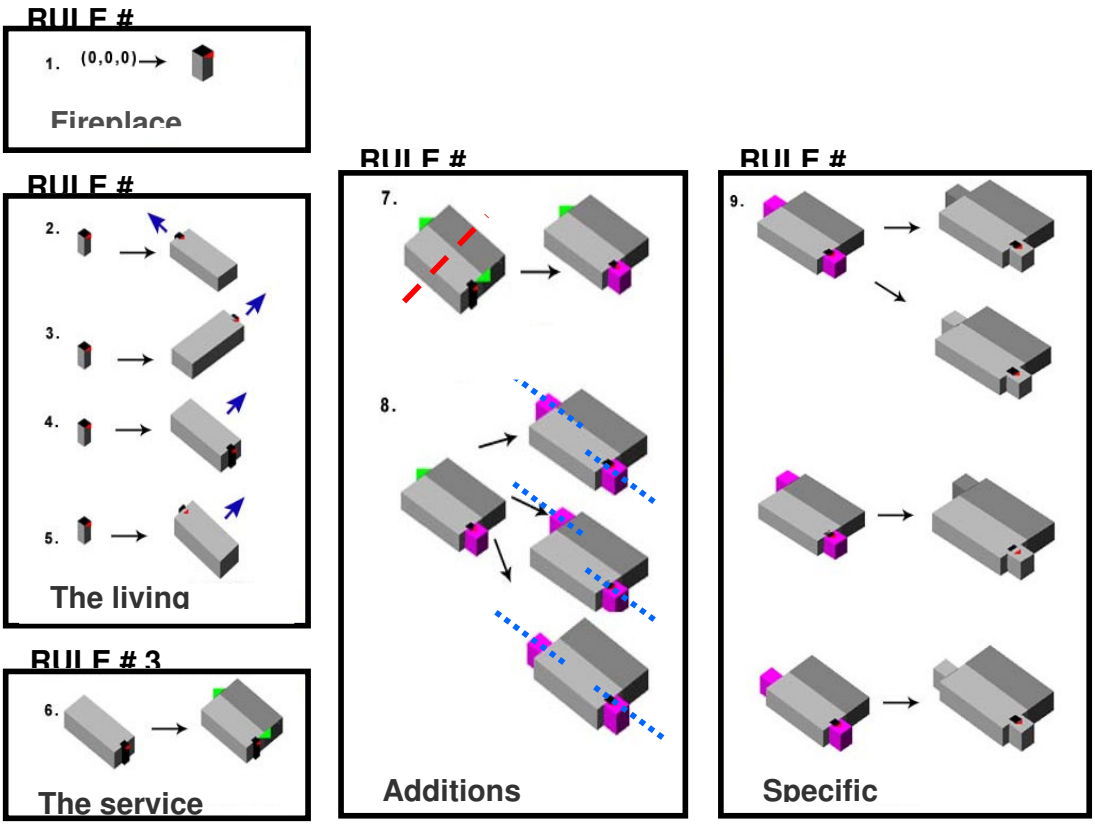

Figure 5. The five house design rules.

This composition may be topped with another block as a bedroom floor. Rule 6, which is optional, adds the second floor to the core. This new set of rules is simple enough to be used in a quick design exercise, but can still represent the essence of the architectural language faithfully.

2. Design Teaching Proposal

A teaching method was devised on the basis of shape grammars and specifically the simplified prairie house grammar shown above. In this method grammars were experimented conceptually through the physical manipulation of Styrofoam building blocks. This design education proposal was tested with a group of students, who gained theoretical knowledge and practical design experience.

Architectural theory was introduced through discussion and experimentation of the design principles of Frank Lloyd Wright. The idea of design methods was briefly introduced to give students a conceptual background on shape grammars and their place in the history of design theory.

This design exercise was exclusively based on the manipulation of three-dimensional physical models or building blocks. The use of these blocks was important to enable students to freely experiment with shapes. These blocks and the grammar can be translated into computational solids and thus may stimulate the use of CAD at an early stage of design development. In our experiment this was only discussed with students.

The design studio experiment was divided into several phases as shown below.

1. Architectural theory was given through a quick lecture on Frank Lloyd Wright and specifically his Prairie House period. These houses were designed and built from 1898 to 1909. Students were presented to each house and analyzed their architectural characteristics, and were asked to recognize patterns of design and a vocabulary of construction elements. The teaching experiment was tested with beginning architecture students, who were not familiar with this period of the architect. This theoretical introduction served to broaden the students' view on architecture, often not fully discussed in other disciplines where emphasis is given to local professionals and historical developments.
2. Shape Grammar theory was introduced to students through another short lecture. A brief history of design methods was given and shape grammars were place in the context of the first generation of design methods. Students discussed architectural theory in relation to shape grammars. Some architects such as Palladio were shown to have specific logical ways of constructing their buildings, based on rules of harmony, proportions and functional relationships. The discussions also touched on the Prairie Houses of Wright, which follow rules as students had already discovered in the previous course phase. Critics of design methods often point out that architecture cannot be reduced to the application of recipes and that shape grammars may represent a simplification of design principles and processes. In this course experiment students were made aware of the complexities of design. A structured approach of design was shown to help overcome hurdles of the process, but cannot substitute the full involvement of the designer in a specific problem posed. Also the application of a design method is not necessarily a means of success in architectural design. Many

variables must be considered and design problems are traditionally considered "wicked".

3. The simplified grammar of the prairie houses described above, based on "The language of the Prairie: Frank Lloyd Wright's Prairie houses" by Koning, H. & Eizenberg, J. (1981) was then presented to students in a third formal lecture. The vocabulary of shapes and the six rules were described. To exemplify the Prairie House grammar, the instructors made a model of two house designs in the form of simple volumetric building blocks, as shown in figure 6. These examples identified each functional element through different colors and the composition guidelines were drawn on the base plate of each model.

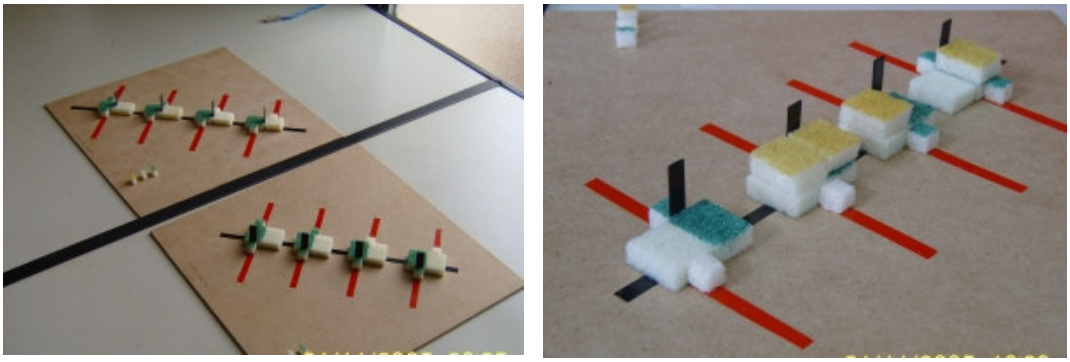

Figure 6. Simple volumetric building blocks

4. After this conceptual introduction students were ready to design on their own. They were given building blocks and developed their own design solutions for a house. The blocks were pre-cut and painted in different colours that defined their functions. A hypothetical location was given with definition of orientation (North Arrow) on the base plate, which also had composition guidelines, allowing dynamic arrangements to be tested (Fig 7). Groups of three students worked on each design. Discussions were held to evaluate each solution developed. Figure 8 shows some of the steps of the design development by the groups. In this phase, manipulation of the functional building blocks was intense. Grammar rules were discussed and solution and their resulting architectural volumes were analysed. Adjustments were made to obtain design (viable forms) and functional logics according to the Prairie House principles.

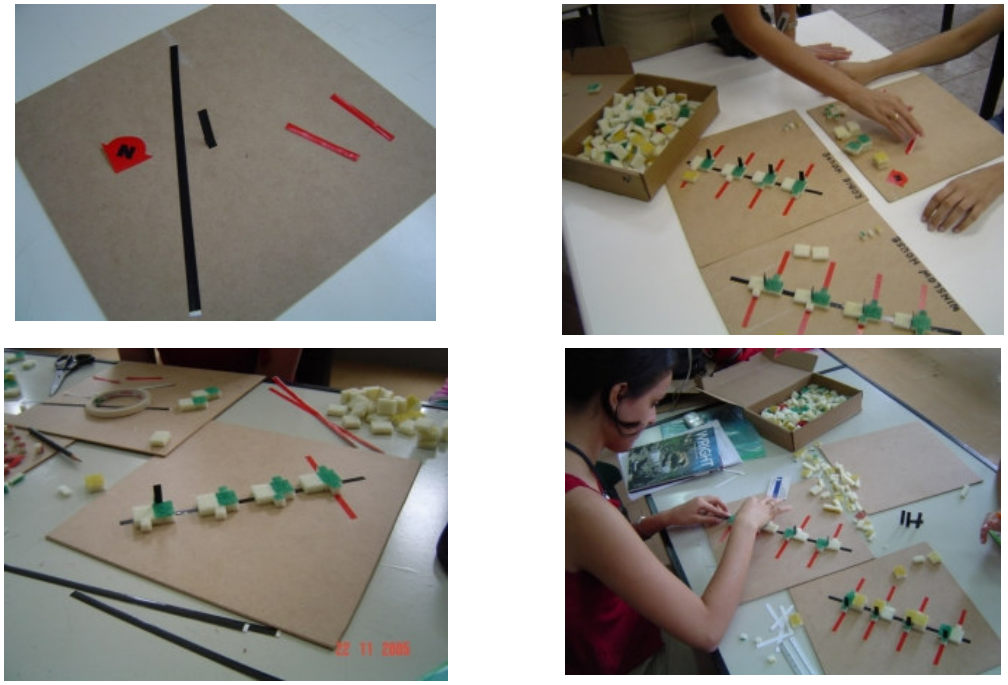

Figure 7. Students ready to start

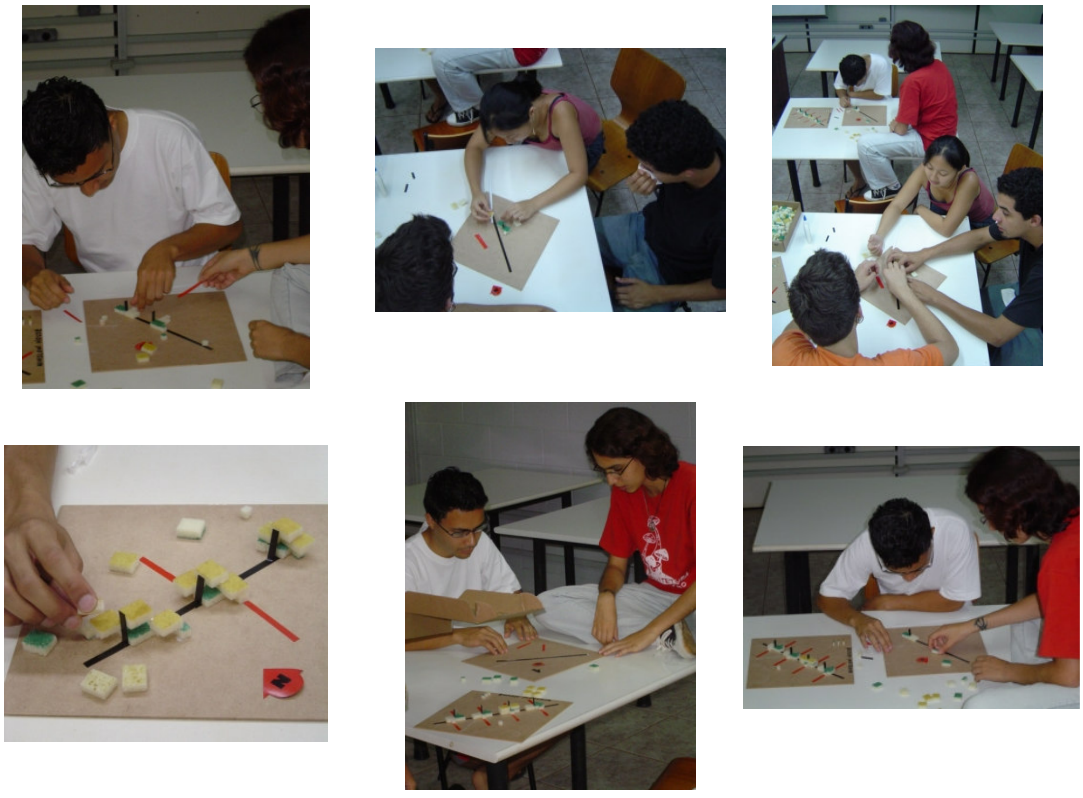

Figure 8. Manipulation of functional building blocks

5. Finally, students presented their designs (Fig. 9) and justified the results according to Prairie House principles and architectural design quality.

Although students applied structured rules to their design compositions, the solutions were innovative and diverse. No “Prairie House” was produced that was identical to known examples. The results showed that the process produced interesting, viable and creative designs and the richness of the students' work demonstrated that the application of rigid rules does not interfere in the creative process. On the contrary, many students invented new rules, such as the cantilevering of the second floor to form a covered area below, which was not present in Frank Lloyd Wright's work, due to technical constraints.

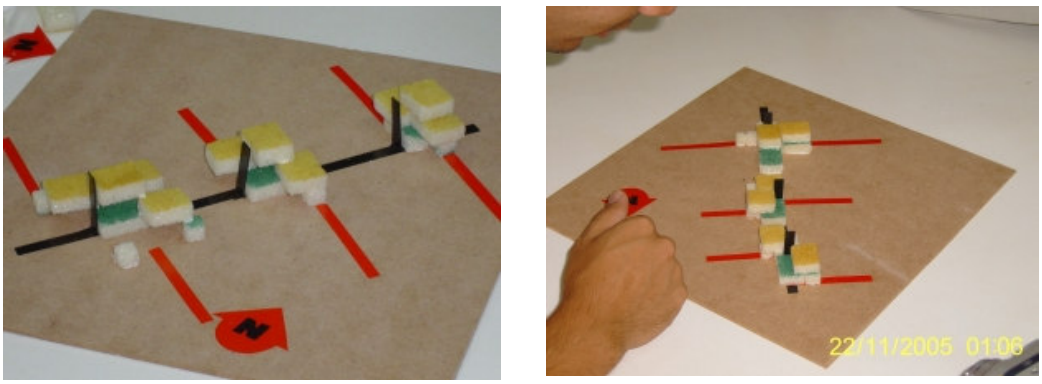

Figure 9. Final presentation of the results

The teaching experiment was highly evaluated by both students and teachers and the discussion on the results touched on the subject of creativity and the way rules, discipline and structure can enhance a design process. Few difficulties were encountered. The students´ learning curve was extremely fast. They assimilated the rules and enjoyed the design manipulation, which gave them more security in reaching viable solutions. The exchange of ideas was rich amongst members of each group. The discussions were focused and typical design subjectivity was reduced.

3. Concluding Remarks

The innovative proposal for teaching design supported diverse activities and had specific goals in mind. Students practiced the manipulation of forms and volumes. Design development was shown in a hands-on way in this method. The teaching experiment of Frank Lloyd Wright's architectural shape grammar can be further tested and developed through computer implementations. The experiment showed that such innovative ways of developing a design project can give studio teachers new insights in architectural education. Important goals in teaching design should be to improve spatial perception and have students acquire structured design methods. Care must be taken to avoid addictions to specific methods and treat design problems in isolation. Design references must be continually and specifically introduced and criticized. Although design is still primarily based on 2D communications design education should use a three-dimensional approach.

The design teaching experiment presented here was part of graduate level course on design methods. This course showed that a variety of activities should be present in the design studio, to break typical lethargies often found in traditional teaching environments The results of this course were made available in the University's distance education environment and are thus open to criticism and refinement. The discussions of the course demonstrated that "teaching teachers how to teach" (triple T) is a challenge and teaching design is not a "cookie cutter" process. Connecting theoretical content with the creative exploration of solutions to problems was shown to be important, as was the application of structured methods. As future developments this teaching proposals should be introduced into the formal studio environment and the evaluation of the quality of student work should be done through crits and competitions.

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